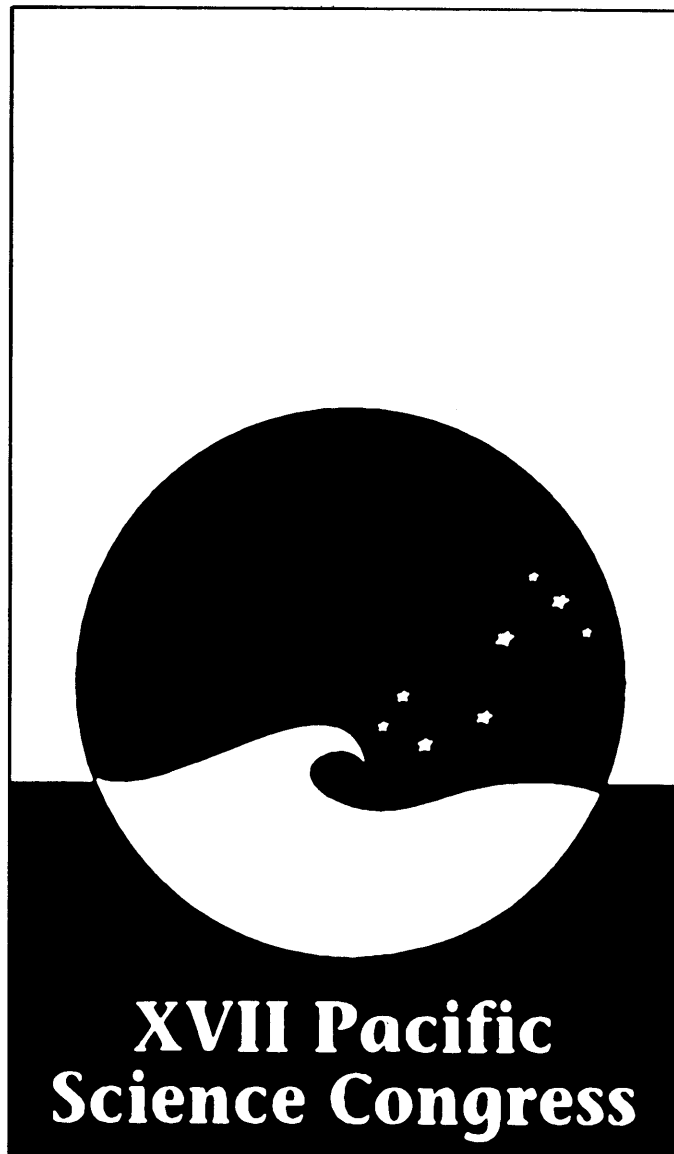


Craniofacial Variation in Pacific Populations

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Post-Pleistocene Change in Australian Aboriginal Tooth Size: Dental Reduction or Relative Expansion?

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ABSTRACT Aboriginal teeth from south-eastern Australia decrease in absolute size during the first three to four thousand years of the Holocene. However, this change in tooth size is not evenly distributed throughout the dental arcade and is more evident in males than in females. Accompanying this reduction in tooth size is a reduction in the size of the cranium, facial skeleton and body. Relative to the reduction in the size of the skeleton the teeth actually increase in size by several percent. Although rates of dental attrition decrease over the same time period it is unlikely that there was any relaxation in the selection for a large and robust masticatory apparatus. Acute dental attrition, with pulp exposure and abscess development, is a feature of both Late-Pleistocene and Holocene Australian Aboriginal populations. Dental reduction in the south-eastern Australian Holocene was probably secondary to a decrease in overall body size. Body size reduction may have been part of a thermoregulatory adaptation to increasing Holocene air temperatures.

There is now a considerable body of data describing an apparently global trend for reduction in the size and robusticity of the human dentition in the post-Pleistocene period. Although there is some variation in the timing and extent of the events involved dental reduction in this period has been recorded from South and East Asia (Brace, 1978; Brace and Nagai, 1982; Brace et al., 1984; Kennedy, 1984; Kennedy et al., 1987; Lukacs, 1984), Europe (Fruyer, 1978; Y'Edynak, 1989), the Mediterranean (Le Blanc and Black, 1974), Africa and the Levant (Calcagno, 1986; Carlson and Van Gervan, 1977; Smith et al., 1986) and Australia (Brace, 1980; Brown, 1987, 1989). Preservational bias has favoured an emphasis on dental data, however, where the orofacial skeleton, cranial vault and other parts of the skeleton are present it appears that there has been a significant reduction in the entire masticatory system and skeletal mass in general (Brown, 1987; Brown, 1989; Carlson, 1976; Kennedy et al., 1987; Smith et al., 1984, 1985, 1986).

Although there is general agreement as to the presence of a post-Pleistocene trend towards reduction of the human masticatory system there is considerable debate as to the evolutionary mechanisms involved. The majority of workers in this area have argued for some connection between cultural development and reduction of the masticatory system. Most of these have focused on the increasing pre-masticatory preparation of food and the greater use of carbohydrate staples which accompanied the

development of agriculture and use of pottery cooking vessels (Brace and Mahler, 1971; Calcagno and Gibson, 1988; Fruyer, 1978; Kennedy et al., 1987; Le Blanc and Black, 1974; Lukacs, 1984; Y'Edynak, 1978). Although there is a general correspondence between these cultural developments and accelerated dental reduction, correlation does not imply causation and there is continued debate over the biological processes involved (Calcagno and Gibson, 1988; Macchiarelli and Bondioli, 1986). It is possible that dental reduction was secondary to skeletal reduction, with selection for smaller body size due to climatic change (Brown, 1987, 1989) or higher population densities and increased competition for resources (Macchiarelli and Bondioli, 1986). Under these conditions it has been proposed that smaller teeth could result from a reduction of the developmental areas available for the teeth (Sofaer, 1973; Sofaer, et al., 1971a), an allometric association with jaw size reduction (Robinson, 1954), or selection favouring a smaller and uncrowded dentition within the reduced facial structure (Brown, 1987; Macchiarelli and Bondioli, 1986).

Skeletal and dental materials recovered from south-eastern Australia provide a useful test of the links between cultural development and post-Pleistocene reduction in tooth size. For most of its human history Australia has been a relatively isolated place. Where undisputed evidence of cultural and genetic contact with smaller toothed populations to the north and north-east is present it is confined to the extreme

north of the continent (Kirk, 1981). At the same time the first Australians were hunter-gatherers 40,000 years ago much as they were at European contact (White and O'Connell, 1982). This is not to imply that an atmosphere of extreme cultural conservatism and minimal technological change prevailed. Developments in stone tool and food preparation technology in prehistoric Australia include the appearance of edge ground tools in the late-Pleistocene (Rosenfeld et al., 1981; Schrire, 1982; Morwood and Trezise, 1989), microlithic backed blades and bifacial points at 4000-5000 years BP (Johnson, 1979; White and O'Connell, 1982) and seed grinding stones in the early to mid-Holocene of the arid region (Smith, 1986). However, neither agriculture or pottery cooking vessels were present before European contact. Moreover traditional diets, and non-masticatory tooth use, in south-eastern Australia required considerable muscular effort and inevitably resulted in acute dental attrition (Kreft, 1862; Beveridge, 1883; Curr, 1889; Campbell, 1939; Barrett, 1977; Brown, 1989). If the dietary models presented in explanation of human dental reduction by Brace (1964, 1967), and others, are correct then you would not expect to find evidence of directional reduction in tooth size in this type of masticatory environment.

Macchiarelli and Bondioli's (1986) suggestion that dental reduction was linked to body size reduction, increasing population densities, disease load and greater stress on resources may be of some relevance to the Australian situation. Lourandos (1983, 1985) and Ross (1985) have argued that a late-Holocene "intensification" in landuse was a feature of south-eastern Australia. The claims for intensification include a greater number of archaeological sites, greater depth of deposit in these sites, the rise of 'villages' and large scale permanent campsites, and greater density of graves in cemeteries (Ross, 1985; Williams, 1987; Pardoe, 1988). However, the archaeological evidence of intensification and the way it should be interpreted has been subject to some criticism (Beaton, 1983, 1985; Brown, 1989; Head, 1990; Bird and Frankel 1991). The chronological basis for the intensification claims are poor and it is not at all clear whether the apparently greater number of younger sites is simply an artifact of preferential preservation and greater site visibility. Whatever the historical reality of the Australian intensification phase population densities and resource pressure did not approach those associated with

the more sedentary lifestyles reported by Macchiarelli and Bondioli (1986).

It has been suggested that a reduction in tooth size may have been secondary to a reduction in the size and prognathism of the orofacial skeleton, or body size in general (Baillit and Friedlaender, 1966; Carlson and Van Gervan, 1977; Smith, 1982). Smaller teeth may then result from a reduction in the developmental areas available for the teeth (Sofaer et al., 1971a, 1971b; Sofaer, 1973), an allometric association with some aspect of body size or facial proportions (Anderson et al., 1975; Glanville, 1969) or selection favouring the maintenance of correct physiological function (Brown, 1987; Calcagno and Gibson, 1988). Comparisons of terminal Pleistocene human skeletons, and crania, from south-eastern Australia have demonstrated that they are considerably larger and more massively constructed than those from the mid to late-Holocene (Thorne and Macumber, 1972; Thorne and Wilson, 1977; Brown, 1987, 1989, 1992). Both cultural and environmental mechanisms have been promoted in explanation of post-Pleistocene reduction in Australian Aboriginal skeletal and dental mass (Brown, 1989; Pardoe, 1991). However, the possibility that diachronic change in the Australian Aboriginal masticatory complex could be directly linked to an altered masticatory environment has not previously been examined in any detail. In part this is because the archaeological record from south-eastern Australia provides little support for this hypothesis. It is also unclear whether the directional change in tooth size reported for the early part of the Australian Holocene is what might be predicted given the reduction in body and skull size over the same time period. The objective of this paper is an examination of post-Pleistocene change in Australian Aboriginal tooth size when placed in this broader perspective.

MATERIALS

The skeletal and dental materials used in this analysis come from the Murray River region of south-eastern Australia. The late-Pleistocene series (L-P) is composed of crania and skeletons from Kow Swamp (Thorne and Macumber, 1972), Cohuna, Coobool Creek and Nacurrie (Brown 1987, 1989, 1992). The sample sizes and dates for each of these sites are listed in Table 1, with Brown (1989) providing additional background information. Each of

TABLE 1. Sample sizes and dates for the Late-Pleistocene, Mid-Holocene and Late-Holocene samples.

Sample	n	Method	Date ¹	Reference
Late-Pleistocene				
Coobool Creek	32	U/Th	14300 ± 1000	Brown 1989
Kow Swamp	9	¹⁴ C	13000 ± 280 - 9590 ± 130	Thorne 1969, 1975, 1976
Nacurrie	2	AMS	11440 ± 160	Brown 1992
Cohuna	1	Morph.	13000 - 9000	Brown 1987, 1989
Mid-Holocene				
Roonka	8	¹⁴ C	7000 - 4000	Pretty 1977; Brown 1989
Barham	6	¹⁴ C	5400 ± 90 - 4670 ± 110	Daley 1986
Keera Station	12	¹⁴ C	5900 ± 550 - 4170 ± 200	Blackwood and Simpson 1973
Late-Holocene				
Swanport	59	Morph.	Recent-European contact	Brown 1989; Pietruszewsky 1990

¹Where more than one date has been reported from a site the range of the published dates are given.

these L-P sites is in close geographic proximity and the skeletons from them share a suite of morphological, metrical and culturally induced traits. In particular, I have argued (Brown, 1981a, 1989) that some of the crania from each of these sites are artificially deformed. To a large degree the dating of the Coobool Creek skeletons is dependent on these morphological characteristics as contamination from modern gelatin, which was used to preserve the skeletons in the 1950's, has precluded meaningful radiocarbon dating. Similarly, the age of the Cohuna cranium is dependent upon morphological and metrical comparison with Kow Swamp and Nacurrie (Brown, 1989, 1992). In compliance with the wishes of Aboriginal communities in the central Murray River region all of the skeletons from these L-P sites were recently reburied.

The mid-Holocene sample (M-H) was drawn from the prehistoric cemeteries at Barham, Roonka and Keera Station. The Roonka site is particularly complex and the stratigraphic relationships and dating of the burials within the site are still being refined. On the basis of Pretty (1977) the skeletons included in the M-H Roonka sample all appear to be older than R48, which has a ¹⁴C date of 3930 ± 120, and younger than 7000 years BP. Poor preservation of much of the M-H sample greatly reduced the numbers available for metric comparison of orofacial development. The Keera Station skeletons were reburied in September 1991. Although undated, morphological and metrical comparisons involving the Swanport crania

have repeatedly associated them with late-Holocene (L-H) Aboriginal series (Pietruszewsky, 1979, 1984; Pardoe 1984; Brown, 1989). The presence of interproximal cervical dental caries, unknown in prehistoric Australian contexts, suggests some contact with European derived carbohydrates and strengthens the argument for a relatively modern date. Swanport formed the largest L-H Aboriginal skeletal population, from southeastern Australia, which remained available for study in 1991.

METHODS

In both the prehistoric past, and European contact period, there was marked regional variation in the mortuary practices employed by Australian Aborigines (Meehan, 1971). Within regions this variation extended to the differential treatment given to particular sexes, particularly males. This appears to be reflected in the apparent sex bias of some museum collections. The potential for cultural bias in sex representation, combined with the pronounced sexual dimorphism recorded for Aboriginal tooth size (Barrett et al., 1963a, 1963b, 1964; Townsend and Brown, 1979; Brown, 1989), required that the sample be subdivided on the basis of sex. The alternative would be to admit the possibility that diachronic trends in tooth size were simply an artifact of the sex distribution of the samples. There was also a possibility that males and females displayed different patterns of diachronic dental change.

Isolated teeth were not included in the analysis and sex was determined through a combination of the morphological and metrical method developed specifically for adult Aboriginal crania by Larnach and Freedman (Larnach and Freedman, 1964; Brown, 1981b), discriminant function analysis of the crania (Brown, 1989) and a morphological comparison of the associated pelvis and sacra (Washburn, 1948; Phenice, 1969). Only 9 of the L-P sample had postcranial skeletons which were complete enough for reliable sex assessment.

Prior to the shift to European derived foods, and methods of food preparation, marked occlusal and interproximal attrition was a feature of Aboriginal dentitions (Campbell and Gray, 1936; Campbell, 1939; Barrett, 1977). For example, in the Murray River region by the time a person had reached 16-17 years of age an average of 3.9% of the occlusal surface of the maxillary first molar was comprised of exposed dentine. At the same age there is considerable reduction of the mesiodistal dimensions, of most teeth, through interproximal attrition. Due to the effects of attrition measures of tooth crown area, or tooth length, tell you something about masticatory function and individual age in these dentitions but convey little in the way of phylogenetic information. For this reason the only measure of tooth size that was recorded for this analysis was the buccolingual crown dimension (Townsend and Brown, 1979), which was recorded to the nearest 0.1 mm. Both Alvesalo and Tigerstadt (1974) and Townsend and Brown (1978) obtain high heritability estimates for this dimension, but the later also found that variance due to common environment was greater with the buccolingual than the mesiodistal dimension. Teeth in which the buccolingual dimension was influenced by attrition were excluded from the analysis.

Student's *t* test is used to assess the significance of differences in mean buccolingual tooth dimensions. This test assumes that variables are normally distributed and there is equality of variance between the groups. Distributions were examined by plotting individual values against corresponding percentage points of a standard normal variable (Gnanadesikan, 1977) and through the use of the Shapiro-Wilk statistic (Shapiro and Wilk, 1965). Homogeneity of variance was examined using the χ^2 test developed by Bartlett (1937). Where a statistically significant difference in variance was indicated by χ^2 , Student's *t* is calculated using the formula based on separate

variance estimates (Snedecor and Cochran, 1967). Graphical comparisons of the distribution of data from different samples are made using the Box plots developed by Tukey (1977). In these plots the box contains the central 50% of the distribution and the horizontal bar passing through the box is the median. The whiskers projecting from the box normally indicate the spread of the upper and lower quartiles, with outliers represented by asterisks (*). Variation in facial size and shape, presence of outliers, distance between group means and group allocation were examined using direct discriminant function analysis (Tabachnick and Fidell, 1989). Variable selection was influenced by preservation, the wish to maximise the number of individuals included in the analysis and the underlying assumptions of distributional normality, and homogeneity of variance and covariance, inherent in discriminant function analysis (Gilbert, 1969; Eisenbeis and Avery, 1972; Huberty, 1984). Missing data decreased the M-H and L-P female samples to such a small size (<7) that there were too few cases to be non-singular, so the females were excluded from the analysis. Linear dimensions and angles follow those used in (Howells, 1973) and Brown (1989). Statistical calculations were performed using SPSS 4.0 (SPSS, 1990), SYSTAT 5.1 (Wilkinson, 1989) and hand calculation.

Several of the arguments developed in explanation of post-Pleistocene human dental reduction concentrate on changes in diet and food preparation technology (Brace and Mahler, 1971; Carlson and Van Gervan, 1977; Calcagno, 1986). The possibility of an association between tooth size and cultural development was examined through a comparison of the relative rates of dental attrition in the L-P and L-H samples. Recent problems concerning access to a large part of the M-H series prevented its inclusion in the attrition analysis. Using the procedures outlined in Richards and Brown (1981) dental attrition was measured as the ratio of the area of exposed dentine to total crown area when viewed from the occlusal. Attrition scores were transformed to logarithms (\log_{10}) to improve the linear relationship between the points prior to principal axis analysis. Age independent rates of wear for the L-P and L-H samples were determined from the attrition scores for the first and second maxillary molars, in combination with the principal axis method advocated by Scott (1979). Plotting of attrition scores did not